Knowledge Requirements – An Integrated Wetland Monitoring Program for Alberta's Oil Sands Region

Program Goals, Questions, and Monitoring Approach

Alberta Biodiversity Monitoring Institute

6/30/2016

Acknowledgments

This report was commissioned by the Alberta Environment, Monitoring, Evaluation and Reporting Agency (AEMERA) acting on behalf of the Biodiversity Component Advisory Committee (CAC) of the Joint Oil Sands Monitoring (JOSM) Program. We thank all of the wetland experts and stakeholders who participated in the stakeholder engagement process. Your time, perspectives, and willingness to share your opinions are greatly appreciated. We thank the Biodiversity CAC committee for their assistance and direction, specifically Ted Nason and Samantha Song. We thank Monique Dubé and Danielle Cobbaert for their review and guidance in capturing the needs of the Alberta Energy Regulator (AER), Shannon White for her review and recommendations related to Land-Use Framework needs, Matthew Wilson for his perspective and review related to the Alberta Wetland Policy, and Kelly Munkittrick for his review and perspective from Canada's Oil Sands Innovation Alliance (COSIA). We thank Golnaz Azimi and Anne Huizinga for their Workshop facilitation support. We also thank the many people that provided direction, advice, and expertise including Jan Ciborowski, Brian Eaton, Theo Charette, Shari Clare, Faye Wyatt, Ted Nason, Bin Xu, Naomi Krugman, Pamela Foster, Tara Narwani, Crisia Tabacaru, Kurt Illerbrun, Elyse Williams, and Lindsay Monk.

How to Cite this Document

Roy, M.C., J. Kariyeva, J. Herbers, and J. Schieck. ABMI 2016. Knowledge Requirements – An Integrated Wetland Monitoring Program for Alberta's Oil Sands Region. Report for the Alberta Environment, Monitoring, Evaluation and Reporting Agency (AEMERA).

For questions related to the project please contact *roy4@ualberta.ca or kariyeva@ualberta.ca*

Contents

List of Figures

List of Tables

Introduction

The well-being of Alberta's economy is intimately linked to the development of natural resources including oil and gas, food and fiber. Similarly, the well-being of Albertans is linked to the health of our environment. Responsible economic and environmental management go hand in hand and neither is optional. Both natural resource development and environmental management require sound environmental information as the bases for decision-making.

This project focused on wetland monitoring needs in the Oil Sands Region (OSR) of Alberta, including the Athabasca, Peace River, and Cold Lake deposits (Figure 1), where wetlands comprise 50% of the land area (Figure 2). An integrated and scientifically robust wetland monitoring program for the OSR is the most effective tool for generating information about the condition of this sensitive ecosystem. Alberta must have, and must be seen to have, a highly credible wetland monitoring system to support current and future land-use decisions.

The goal of this project was to design a scope for a monitoring program that addresses locally and regionally relevant questions related to the condition of wetlands in the OSR.

This project had six components[1]:

1. Engage wetlands experts and stakeholders to develop and identify the critical elements of a wetland monitoring program for the OSR[2].
2. Review key environmental legislation, policies, strategies, and management frameworks to further characterize wetland monitoring needs for the OSR[3].
3. Identify drivers of wetland change, associated stressors and potential response variables. Use this information to further refine the selection of wetland indicators[4].
4. Review existing wetland field[5] and remote sensing[6] monitoring activities in the OSR to identify gaps and integration possibilities.
5. Develop scientific recommendations for consideration in designing a detailed sampling strategy[7].
6. Consolidate the body of the above components into a final report (present document).

---

[1] Refer to Appendix 7 for a list of all documents supporting this report.
[2] Refer to the supporting document *Identifying the Scope and Objectives of the Wetland Monitoring Program – A Three-Phased Stakeholder Engagement Process* for a summary of the engagement process.
[3] Refer to the supporting document *Wetland Management and Monitoring Needs – A Review of Alberta's Environmental Legislation, Regulations and Policies Related to Wetland Management* for a review of key environmental legislation pieces.
[4] Refer to the supporting document *Stressors and Indicators of Wetland Change in Alberta's Oil Sands Region – Potential for Use in Wetland Monitoring.*
[5] Refer to the supporting document *Review of Wetland Field Monitoring Programs in Northeastern Alberta* for a review of existing wetland monitoring programs.
[6] Refer to the supporting document *Review of Remote Sensing Methods for Monitoring Wetlands in Northeastern Alberta* for a review of existing remote sensing technologies.
[7] Refer to the supporting document *Monitoring Designs to Assess Cumulative Effects and Stressor-Response Relationships* for further details about sampling design and statistical power considerations.

Out of scope for this project was the detailed design or implementation of a wetland monitoring program for the OSR. As a result, specific sampling designs, protocols, and standard operating procedures will be left to the next step in program development.

This project was guided by a Technical Team composed of representatives from the Alberta Environment, Monitoring, Evaluation and Reporting Agency (AEMERA) and the Alberta Biodiversity Monitoring Institute (ABMI).

During the development of the wetland monitoring program we also sought strong alignment with goals, objectives, approaches and strategies developed by the Alberta Energy Regulator (AER)[8]. To accomplish this we engaged with representatives from the AER-initiated EPEA[9] Oil Sands Mine Wetland Monitoring Program Working Group[10] throughout the development process.

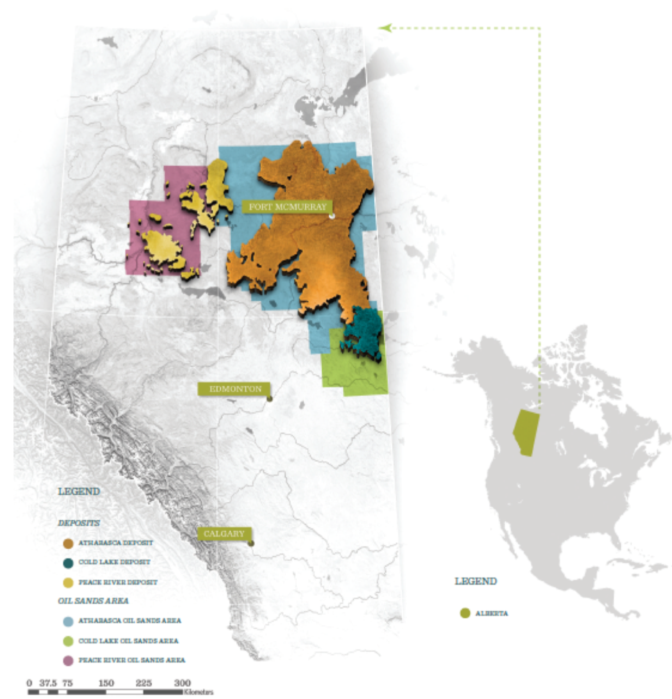

Figure 1: Alberta has three major oil sands deposits – the Athabasca, Cold Lake, and Peace River deposits. Each deposit is associated with an administrative unit (oil sands area) of the same name. Collectively these make up the Oil Sands Region.

---

8 In parallel to this program, AER developed a wetland monitoring program as part of the industry regulatory approvals under the Environmental Protection and Enhancement Act (EPEA). EPEA Oil Sands Mine Wetland Monitoring Program Working Group was initiated by AER in December 2015 and was composed of representatives from AER, AEMERA, Alberta Environment and Parks (AEP), Canadian Association of Petroleum Producers, and COSIA. For further details refer to Appendix 8 (*EPEA Oil Sands Mine Wetland Monitoring Program Recommendation Report*).

9 EPEA: Environmental Protection and Enhancement Act

Wetlands in the Oil Sands Region

The scope of the integrated wetland monitoring program is identified as the OSR. This region covers an area of 142,200 square kilometres (Figure 1) or 21% of Alberta's total area (CAPP 2013). The region is a vital contributor to Alberta's economy with agriculture, forestry, and 97% of Canada's oil reserves in three oil sands deposits: Athabasca, Cold Lake, and Peace River.

More than 50% of the region (Figure 2) supports peatland (i.e., fen and bog) and mineral wetland (i.e., swamp, marsh, and shallow-open water) vegetation (Vitt et al. 1996). Wetlands provide a wide range of critical ecosystem functions and services. Considered as "biological supermarkets", wetlands are dynamic ecosystems that support rich biodiversity, large and complex food chains, and provide essential habitats for wildlife (Mitsch and Gosselink 2011). In the boreal region, they are breeding grounds for millions of ducks and other waterfowl (Slattery 2016). Wetlands filter and enhance water quality, stabilize water supplies and soils, and thereby help ameliorate both floods and droughts (de Groot et al. 2002).

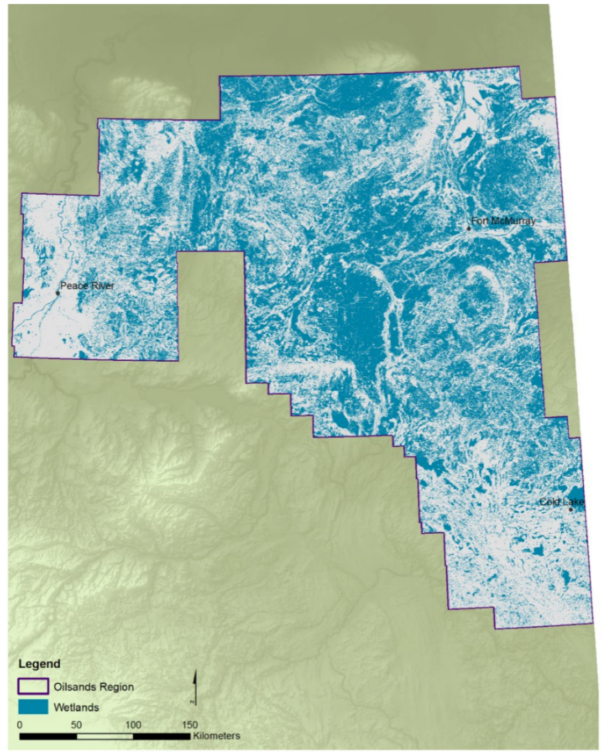

Figure 2: Wetlands in the Oil Sands Region of Alberta compose 50% of the landscape.

Development Stages for the Wetland Monitoring Program

Four stages must be considered in creating the integrated wetland monitoring program for the OSR (Figure 3). Each of these stages is required for the monitoring program to be effective at supporting information needs of stakeholders in the OSR. The stages are:

1. Design – developing information programs:
    - Knowledge requirements – understanding information needs and desired uses **(*purpose of our current project*)**;
2. Monitoring – developing and implementing the program (next step; led by scientists):
    - Program development- developing and validating sampling design and protocols.
    - Data acquisition – operational implementation of protocols;
3. Evaluation- developing database, ensuring quality control of data, and performing data analysis:
    - Data management – receiving, cleaning and storing data;
    - Data analysis – developing and implementing scientific analysis;
4. Application- developing and implementing integrated knowledge systems
    - Knowledge translation – making results available, synthesizing and conveying information to stakeholders.

Figure 3: Stages in the development of an integrated wetland monitoring program for the OSR.

We see a logical flow through these stages that define the operational aspects of an environmental monitoring system. This logical flow provides a framework for ensuring that all aspects of the wetland monitoring program are being considered.

Core Design Principles

The long-term success of an integrated wetland monitoring program for the OSR requires that it have the following core principles[11]:

1. **Credibility (Scientific Credibility):** Stakeholders must judge the information that arises from the monitoring program as scientifically sound (Cash et al. 2002, 2003). Achieving and maintaining a high degree of scientific credibility requires that the principles of openness, peer-review, fairness, and honesty (Ford 2000) be institutionalized within the wetland monitoring program.
2. **Relevance**: Information produced by the wetland monitoring program must meet the needs of stakeholders in a timely manner (Cash et al. 2002, 2003). In the context of wetland monitoring, relevance will be determined by the relevance of the questions addressed, the study design

[11] Refer to Appendix 1 (*Guiding Principles in Details*) for a detailed list of core design principles.

used to address questions, the appropriateness of analysis and communication methodology, and the timeliness of the information.

3. **Legitimacy**: information produced by the wetland monitoring program must be viewed as politically and procedurally fair (Cash et al. 2002, 2003). Legitimacy fundamentally deals with the "…perception that the production of information has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests" (Cash et al. 2003).
4. **Accountability**: There must be clear accountability in the operation of the wetland monitoring system for the OSR.

Successful operation of an integrated wetland monitoring program must consider these four design principles while also ensuring that there is predictable and stable funding model for the program. With stable funding comes a responsibility for the program to be highly cost-effective. There is a strong expectation by all stakeholders that the program ensures harmonization in protocols, avoids duplication, and adopts an integrated design where practical.

Wetland Monitoring Goals

During the stakeholder engagement process, participants collectively identified the mission for the monitoring program: the monitoring program must support improved decision-making related to the specific- and cumulative effects of anthropogenic activities on wetlands in the OSR. Energy, forestry, agriculture, and urbanization are examples of anthropogenic activities occurring in the OSR. As these pressures intensify, they are likely to contribute both individually and collectively to cumulative environmental impacts.

In this context, we characterize monitoring needs as primarily local[12] or regional[13]. These two categories are not exclusive, but reflect two major elements of stakeholder input:

1. Specific effects are often local in nature and backstopped by the EPEA, the Alberta Wetland Policy (AWP), and related legislation[14];
2. Cumulative effects[15] are often regional in nature and covered by policies including Alberta's Water for Life Policy and the Land-use Framework.

Neither monitoring need is exclusive of the other and both "scales" are likely critical to the build-out of an integrated wetland monitoring program for the OSR (Figure 4). Understanding the influence that anthropogenic activities have on changing[16] wetland conditions[17] is critical to both scales.

---

[12] Local refers to site-specific, sector-specific, and/or project-specific monitoring in, for example, the surface minable region of the OSR.

[13] Regional refers to the Oil Sands Region of Alberta.

[14] For a complete review of key wetland-related legislations, policies, frameworks and strategies in Alberta and their respective wetland management mandates refer to the supporting document: *Wetland Management and Monitoring Needs.*

[15] Cumulative effects are defined as effects on the environment that are caused by the combined results of past, current and future anthropogenic activities (Elvin and Fraser 2012).

[16] Change is defined as departure from the natural range of variability of wetlands.

[17] Wetland condition refers to the state of the biotic and abiotic components of wetlands and is mainly evaluated on the basis of selected indicators that are monitored in the field or remotely.

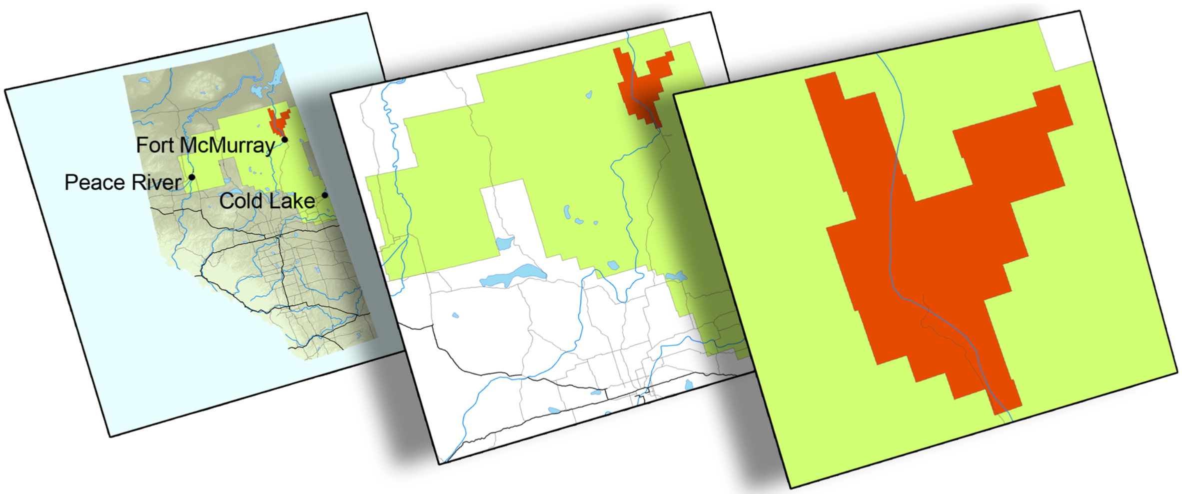

Figure 4: The integrated wetland monitoring program for the OSR operates at two spatial scales - Regional (broader area in light green) and Local (e.g., surface minable region in orange).

Two monitoring goals are recommended to support the monitoring and management needs of the industry (e.g., oil and gas, forestry, and agriculture), the government, and other stakeholders (e.g., ENGOs, environmental consultants) in the OSR. These two goals are:

Goal 1 – Local

Detect changes in wetlands that are associated with specific anthropogenic activities (stressor-response, sector, operator, site-specific)

Directly aligning with the mandates of the EPEA and the AWP, Goal 1 supports the needs of stakeholders that are principally focused on mitigating the effect of a specific stressor-response relationship in wetlands adjacent to industrial operations such as oil sand mines[18]. This monitoring goal operates at a local scale and supports management needs and actions relevant to a specific sector, operator, or site.

Goal 2 – Regional

Detect changes in wetlands that are associated with multiple anthropogenic activities occurring at a regional scale (cumulative effects, industry, and regionally relevant)

Goal 2 is aligned with the mandates of numerous federal and provincial legislations, policies, frameworks and strategies that are designed to manage wetlands at a provincial, regional, or sub-regional scale. For example, the Water for Life Strategy and the Land-Use Framework require information to support large-scale management (e.g., the Athabasca River Basin and Lower Athabasca Regional Plan).

Under an integrated design, information collected under Goals 1 and 2 can be highly complementary, and stakeholders participating in the engagement sessions recognized the need for strong integration between monitoring activities associated with both goals. For example, stakeholders can use regional-

[18] Operations can be related to various sectors, such as urban development, and the agriculture, forestry, and oil sands industry. These operations can occur in the mining and in the in situ area of the oil sands region.

scale information to better understand local wetland change (e.g., by providing reference conditions or explaining natural wetland change). Similarly, stakeholders can use local-scale information to better understand drivers of wetland change that may be occurring throughout a region. The wetland monitoring program for the OSR will significantly benefit from an integrated approach to monitoring.

Integrated Approach to Wetland Monitoring

The conceptual approach to developing an integrated wetland monitoring program includes four phases of monitoring (Figure 5): Surveillance, Confirmation, Focused study (Association), and Causation. This approach supports both local-scale monitoring (Goal 1) and regional-scale monitoring (Goal 2). These four phases may be run sequentially with each phase being "triggered in" by results in the previous phase. A robust wetland monitoring program will, *a priori*, design data collection to accommodate scientific analysis at more than one of these phases. Designing a wetland monitoring program to meet the analytical needs of multiple phases will save time, enhance relevance, and reduce costs in the long-run.

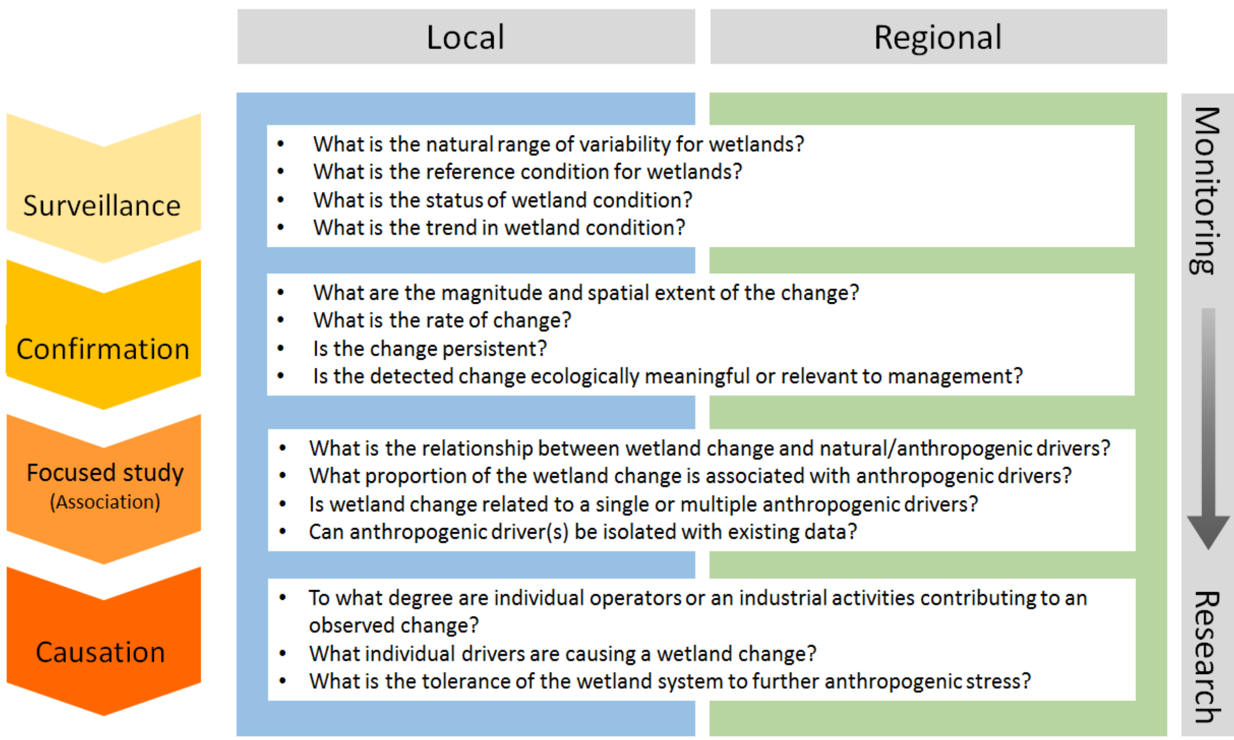

Figure 5: The conceptual approach to monitoring is similar under Goal 1 (Local) and Goal 2 (Regional). The scientific process applies across all areas of the monitoring program. Long-term monitoring dominates at earlier phases while research plays a larger role in later phases. The monitoring system will require field and remotely sensed data at all phases of monitoring.

A complete description of the four investigative phases of the Wetland Monitoring Program follows.

Surveillance Phase:

The surveillance phase is used to establish the status, trend, and natural range of variability in wetland condition. This information is used to define "reference" levels against which any change in condition is compared and reported. The indicators (response variables) tracked are good[19] at detecting an impact but on their own, these indicators may be relatively weak at diagnosing the exact cause of the impact. Questions addressed during this phase include:

- *What is the natural range of variability[20] for wetlands?*
- *How do reference conditions differ among various wetland classes? (e.g., bog, fen)*
- *What is the reference condition of wetlands?*
- *What is the status of wetland condition?*
- *What is the trend in wetland condition?*

Confirmation Phase:

Patterns detected during the surveillance phase are confirmed by gathering additional data and using stronger analysis. The status of wetlands is compared to natural variation or reference conditions in detail to better characterize observed patterns. For example, magnitude, extent and rate of change in condition are assessed in detail. Where appropriate, persistence of the change over time is evaluated or predicted (i.e., how long is the change anticipated to persist?). Questions addressed during this phase include:

- *What are the magnitude and spatial extent of the change?*
- *What is the rate of change?*
- *Is the change persistent?*
- *Is the detected change ecologically meaningful or relevant to management?*

Focused Study (Association) Phase:

Detailed relationships between the observed condition of wetlands and potential drivers are investigated. The effect of natural[21] and anthropogenic factors on the condition of wetlands is partitioned. Although no cause-effect relationship can be established with certainty, this phase of investigation may provide enough clarity to implement a management action if required. This work also supports hypothesis generation (strong inference) that is required in the last phase of investigation. Questions addressed during this phase include:

- *What is the relationship between wetland change and natural/anthropogenic drivers[22]?*
- *What proportion of the wetland change is associated with anthropogenic drivers?*
- *Is wetland change related to a single or multiple anthropogenic drivers?*
- *Can anthropogenic driver(s) be isolated with existing data?*

---

[19] The indicators are sensitive to anthropogenic activities, are correlated with one or many drivers, and provide early indications of change.
[20] Variability across space and time.
[21] Natural factors also include natural disturbances such as wildfire, insect outbreaks, and diseases, and climate change.
[22] Drivers are major external forces that potentially impact wetlands or their watersheds either directly or indirectly (Ciborowski et al. 2012). Drivers can be natural or anthropogenic (Jean et al. 2005).

Causation Phase:

Through research, associations between drivers and the condition of wetlands are further investigated to identify stronger evidence of cause-effect relationships. Additional variables (e.g., drivers, response variables, covariates) selected to be monitored in this phase are used to diagnose the specific cause of the observed change, and therefore their selection is context dependent. The need to establish cause-effect relationships depends, in part, on the resolution of information required by managers and resource developers to guide their management decisions. Under certain circumstances where correlations provide sufficient resolution to inform decision-making, as is often the case with management at a regional scale, cause-effect relationships may not be further investigated. Questions addressed during this phase include:

- *To what degree are individual operators or industry contributing to an observed change?*
- *What individual drivers are contributing to wetland change?*
- *What is the tolerance of the wetland system to further anthropogenic stress?*
- *What drivers appear to offer greatest opportunity for a management response?*

To the degree practical, we recommend that Local (Goal 1) and Regional (Goal 2) Monitoring components of the integrated wetland monitoring program have built-in data collection activities to support the first three phases of investigation; that is, the first three phases should be pre-built into each component of the program. This would leave phase four, causal investigation, to be triggered as required by stakeholders. Management action may occur at any phase. However, stakeholders expressed an interest in having open, ongoing discussion about the certainty and interpretation of data derived from the system. This process would be addressed in Management Response (see Appendix 2).

Monitoring Approaches

> Many terms are used to describe environmental monitoring approaches. Examples include compliance, regulatory, implementation, effects, assurance, issues-based, condition, pressure, response, trend, effectiveness, cumulative effects, surveillance monitoring, retrospective, predictive, stress-orientated, and performance. Wading through these terms, and their numerous meanings, is often a source of frustration, conflict and confusion. Rather than arguing for any specific language, we are selecting general terms to describe the two basic monitoring approaches that stakeholders and literature identified as most relevant to wetland Goals 1 and 2.

To facilitate sustainable management it is necessary to understand the environmental effects of proposed developments on native ecosystems (Hegmann et al. 1999, Alberta Environmental Protection and Enhancement Act 2010). In a wetland context, developments may include activities that alter the vegetation and/or physical characteristics in and around the wetland, or that result in contaminants entering the wetland (Cumulative Environmental Management Association 2012). Some of the environmental changes are very localized and tightly coupled with specific stressors. To understand these stressor-response relationships, either a range of wetlands with varying levels of disturbance is surveyed or disturbed locations are compared to reference locations (e.g., Ciborowski et al. 2010, Rooney and Bayley 2012). At the other end of the continuum, some ecological effects on wetlands result from the cumulative changes of many disturbances throughout the landscape. Due to synergistic effects, these cumulative effects are best tracked by regional monitoring (Haughland et al. 2010, Wintel et al. 2010). If data collection methods are harmonized so that variables are measured similarly by both stressor-response research and cumulative effects monitoring, the resulting information can be used in both analyses, minimizing overall costs. For both types of monitoring, sample size must be optimized so that relationships can be detected at a reasonable cost.

We describe two basic approaches to wetland monitoring– Stressor-response and Cumulative-effect Monitoring.

Stressor-response Monitoring Approach (largely applies to Goal 1)

Stressor-response Monitoring is implemented to understand both the environmental effects that occur during resource exploration and extraction, and the degree to which disturbed areas recover following relief of the stress and/or mitigation efforts. This stressor-response approach is especially important for resource development at a local scale in and near wetlands because hydrological process can be affected by development, and changes in hydrology may compound wetland changes (Cumulative Environmental Management Association 2012). Recovery following development of wetlands, even following temporary vegetation removal, has proven to be slow (Zedler and Callaway 2002, Rooney and Bayley 2011, Kovalenko et al. 2013). In addition, wetland reclamation, especially for bogs and fens, is challenging (Foote 2012, Anderson et al. 2013, Borkenhagen and Cooper 2015). Stressor-response monitoring is required to understand environmental changes for each class of wetland being evaluated, and for wetlands from a variety of landscapes with different amounts and types of upland and lowland habitats, because responses may differ among them.

To understand stressor-response relationships it is efficient to sample the gradient from low (ideally no) development through to high intensity development, and model changes along this gradient (e.g., Nichols and Williams 2006). Since environmental effects occur at a variety of spatial and temporal scales, monitoring and evaluation need to be conducted at several scales (Wintel et al. 2010, Burton et al. 2014). An alternative method to evaluate stressor-response (a method commonly cited in environmental impact assessments) is to use a reference condition approach (Bailey et al. 1998), of which the before-after-impact-control design (BACI) is a special case (Gotelli and Ellison 2004). With these designs environmental conditions are compared between undisturbed (reference) and disturbed (sentinel) locations; for BACI designs conditions are also compared before and after the development. BACI and reference condition designs are commonly used to identify the impacts of specific developments (e.g., Cumulative Environmental Management Association 2012), whereas stressor gradients are used to understand the range of responses that are expected to be encountered throughout the landscape (Gotelli and Ellison 2004).

Cumulative effect Monitoring Approach (largely applies to Goal 2)

Natural environments are complex with many species and habitats interacting in a multitude of ways (Wintel et al. 2010). These interactions fluctuate and change due to different physicochemical characteristics, habitat types, and species communities, as well as species meta-population dynamics that are affected by the same factors (Saunders et al. 1991, Ramalho et al. 2014). There are never enough resources to study all aspects of ecosystems at all spatial and temporal scales. As such, cumulative effects assessment will always be incompletely understood. To overcome these limitations, cumulative effects monitoring throughout the region of interest is used to document existing ecological conditions, trend in condition over time, and to confirm whether the desired conditions are being created (Magunsson et al. 2008, Haughland et al. 2010). Choice of sample locations must be rigorous so that information that is collected can be applied effectively to the complete region of interest. In addition, given the abundant daily, seasonal and inter-annual variation that is found in natural wetlands, monitoring information must be able to separate trend over time from natural variability. If monitoring is well designed, the strongest anthropogenic effects will be highlighted before they become acute so that a management response can be implemented (Burton et al. 2014). It is important to have unbiased sampling during cumulative effects monitoring so that present conditions, and the magnitude of changes over time, can be estimated rigorously. A variety of probabilistic sampling designs are possible, each with their own strengths and weaknesses (Kangas and Maltamo 2006).

Integration of Stressor-response and Cumulative Effects Monitoring

Although monitoring goals and study designs differ between stressor-response and cumulative effects monitoring, many of the same stressors and response variables need to be surveyed for both. By measuring a similar set of base variables during both types of monitoring, information can be integrated between them (Haughland et al. 2010). For example, locations that are surveyed during cumulative effects monitoring could be used to describe part of the stressor gradient in the stressor-response approach, with the rest of the gradient being filled by targeted surveys. In addition, by using cumulative effects information to understand variability throughout a region, it will be easier to generalize results from stressor-response monitoring over broad areas. However, since different people are often involved when developing cumulative effects monitoring than when developing stressor-response monitoring, integration between the two types of monitoring often does not occur (Magnusson et al. 2008). To overcome this issue, it is important to make survey protocols accessible and to strongly promote the use of the same protocols by all organisations (Haughland et al. 2010).

Integrated Wetland Monitoring Program – the Options

We present three options for consideration. The largest difference between these options is in the number and type of wetland indicators embedded in the program (more indicators require more financial resources). The three options are:

- *Basic Wetland Monitoring Program* – Minimum level of investment to operate a credible integrated wetland monitoring program.
- *Robust Wetland Monitoring Program* – Healthy level of investment to ensure a robust, long-term integrated wetland monitoring system is in place today and in the future.
- *Augmented Wetland Monitoring Program* – Priorities for investment as additional resources become available.

Each of these three options will address Goal 1 (Local) and Goal 2 (Regional) but the type of monitoring questions[23] and associated indicators[24] differ. For each of these scenarios, a list of questions (Appendix 3) and a list of indicators (Table A5-1, Appendix 5) and covariates (Table A5-2, Appendix 5) are outlined.

---

[23] Refer to Appendix 3 (*Detailed Monitoring Questions*) for a list of monitoring questions.
[24] Refer to Appendix 4 (*Criteria for Indicator Selection*) for a description of indicator selection process.

The Basic Monitoring Option is composed of only those indicators that are known to respond to existing drivers. By contrast, the Augmented Monitoring Option includes indicators that have been identified as important by stakeholders. However, not all variables of interest to stakeholders make good indicators of wetland condition and scientific research will need to factor substantially in the operation of the integrated wetland monitoring program[25]. Variables of importance to stakeholders were identified primarily during the engagement process. Thus, **we recommend the *Robust* scenario as a basis for building the Integrated Wetland Monitoring Program.** This option represents a compromise; most stakeholders will have most of their information needs met under the Robust Option.

We discuss the Robust Wetland Monitoring Program in the rest of this section.

Wetland Classes (Robust Option)

Treed poor fen, treed rich fen, treed bog, and conifer swamp were identified as four most common wetland classes in the mineable oil sands region (Ciborowski et al. 2012) and represent the priority classes for this monitoring program.

Indicators and Covariates (Robust Option)

The selected indicators represent biotic and abiotic variables. The full list of indicators is provided in Table A5-1 (Appendix 5). The biotic indicators for the monitoring program are:

- Vascular plants;
- Macro-invertebrates;
- Mosses and lichens.

Abiotic indicators include measurements of:

- Water quality (e.g., pH, salinity, nutrients, ions, metals);
- Water quantity (e.g., water depth);
- Soil/sediment quality (e.g., moisture);
- Soil/sediment quantity (e.g., peat accumulation);
- Other wetland characteristics (e.g., total area, area of vegetative zones).

Environmental covariates are also assessed through the monitoring program[26]. Environmental covariates are variables that vary naturally over space and time (e.g., precipitation, soil types) and which influence the condition of wetlands independently of human activities***.*** Tracking and understanding covariates is necessary when interpreting the impacts of drivers, as covariates may influence response variables in wetland systems. Suggested covariates to assess include:

- Wetland geographic location;
- Wetland classes;
- Year of sampling;
- Annual climate parameters (e.g., temperature, precipitation);

---

[25] Refer to Appendix 6 (*The Role of Scientific Research*) for more details about the role of scientific research in the operation of the integrated wetland monitoring program.

[26] Refer to the supporting document *Stressors and Indicators of Wetland Change in Alberta's Oil Sands Region – Potential for Use in Wetland Monitoring* for further details about covariates.

- Natural region and sub-region;
- Watershed order;
- Coarse soil types;
- Coarse vegetation types;
- Surficial geology;
- Parent material deposits;
- Beaver presence;
- Land-use type, occurrence and abundance in or adjacent to wetland.

To address Goal 1 (Local), we recommend the wetland monitoring program be built out using the BACI (before-after-impact-control) design to monitor status and trend (a specialized type of stressor-response monitoring). The BACI design allows each developer to compare the conditions of wetlands before and after their development. By comparing before-after conditions in the development area in parallel with before-after conditions at undisturbed locations, the effects of each particular development can be understood. This approach is best aligned with the needs of the industry, but it needs to be coupled with additional random samples throughout the region to track cumulative effects. By using the same protocols for BACI and cumulative effects monitoring, much of the information can be used in both analyses, decreasing costs for the integrated monitoring program.

To address Goal 2 (Regional), we recommend the wetland monitoring program be built out using cumulative effects monitoring. Cumulative effects monitoring allows existing ecological conditions in wetlands to be documented, and trend in the condition of these wetlands determined over time. Selection of sample locations must be rigorous to ensure that the collected information effectively tracks present condition and the magnitude of change over time for the entire region of interest[27]. In order to facilitate regional scenario modeling and enhance predictive capacity, the regional program will need to invest in a modest level of targeted sampling consistent with the local stressor-response monitoring program. This targeted sampling will directly support stakeholders who manage wetlands at the regional scale (e.g., wetland management needs under the Land Use Framework).

Key Recommendations

The goal of this project was to design a scope for an integrated monitoring program that addresses locally and regionally relevant wetland monitoring questions in the OSR. To enable long-term and sustainable wetland monitoring the key recommendations from this report are as follows:

1. **Relevant and Responsive** – Support management needs of multiple stakeholders (e.g., government, industry, academia, and the public) while informing decision-making and supporting relevant environmental legislation, policies, strategies, and acts.

[27] Refer to the supporting document *Monitoring Designs to Assess Cumulative Effects and Stressor-Response Relationships* for further details about potential unbiased sampling designs.

2. **Integrated and Standardized** – Enable integration in protocols and at points in study designs if possible. Address locally and regionally relevant questions related to the condition of wetlands in the OSR to ensure strong integration between monitoring activities associated with proposed goals (Goal 1 – Local; Goal 2 – Regional). Apply standardized protocols and methods to ensure that the information is reproducible and can be used for different purposes and at various spatial scales (e.g., local to sub-regional and regional).
3. **Timely and Accessible** – Effective delivery of relevant monitoring activities to support the stakeholders in meeting their wetland management and reporting needs. Facilitate seamless transfer of information and data to key stakeholders in an open and transparent manner.
4. **Cost-effective and Scientifically Robust** – Design monitoring, sampling, and analysis protocols to be cost-effective and capable of monitoring a robust suite of indicators over representative spatial scales and long time periods. Coordinate critical aspects of existing programs. The findings (i.e., data and information produced) should be scientifically credible, reproducible, replicable, generalizable, and scalable.
5. **Long-term and Adaptive** – Long-term monitoring can provide important ecological insights and is essential for the management of ecosystems (Lindenmayer and Likens 2009). The program should address well-defined relevant questions that are underpinned by a rigorous statistical design developed by wetland experts working alongside with environmental scientists.
6. **Funding**: The program should be based on a secure and stable funding model. Funding should be predictable over multiple years. Development and delivery of the monitoring program will require well established relationships with the research community and other service providers. We recommend implementing the *Robust Wetland Monitoring Program* option described in this report.

Moving Forward

The integrated wetland monitoring program for the OSR will require continued collaboration, commitment, and communication among all stakeholders and sectors. While there are major gaps in existing wetland monitoring programs, there is potential for integration and opportunities to leverage available resources and foster new and current collaborations and partnerships[28]. At this stage of development (Knowledge Requirements – Figure 3) we used a strong engagement process[29] to identify the goals and questions that the program needed to address; See Appendix 7 (*List of Supporting Documents*) for a list of the technical documents produced as part of the overall project.

The main purpose of the next stage (2016–2017; Program Design (Figure 3)) is:

1. Develop the sampling design of the program. This will require the use of statistical power analyses to optimize sampling layout, frequency and intensity.
2. Develop and/or validate field and remote sensing protocols for selected variables and covariates.

[28] Refer to the supporting document *Review of Wetland Field Monitoring Programs in Northeastern Alberta* for a review of existing wetland monitoring programs.
[29] Refer to the supporting document *Identifying the Scope and Objectives of the Wetland Monitoring Program – A Three-Phased Stakeholder Engagement Process* for a summary of the engagement process.

3. Validate the statistical design – parallel to stages 1 and 2, engage government, industry, ENGOs, wetland experts and other stakeholders from the OSR to get feedback on the proposed design, protocols and program.
4. Parallel to stages 1, 2, and 3, engage with monitoring organizations currently conducting wetland monitoring in the OSR to integrate monitoring programs. Work with existing wetland monitoring initiatives to create an integrated system for the OSR. Integration will include developing methods to fill any gaps that have been identified. Select sites to be monitored under Goal 1 and Goal 2 and develop monitoring protocols.
5. Collect preliminary data to test the developed protocols and calibrate and validate the selected indicators, variables and covariates (pilot the program in modules).

Robust piloting should make up the first activity under the Data Acquisition Stage (Figure 3). This will be followed quickly by a need to manage and analyse the data[30]. During the piloting phase of program development, analyses are conducted and issues are solved as they arise. To accomplish this, the following will need to be implemented:

1) Initiate a pilot of an integrated wetland program in the OSR;
2) Develop capacity to process and manage field and geospatial data that will be collected as part of the piloted monitoring program;
3) Implement preliminary quality assurance/quality control analyses and resolve issues and/or adjust protocols as required.

[30] Numerous stakeholders and wetland experts highlighted that the greatest cost and effort associated with sampling wetlands is typically related to travel to reach the wetland site; therefore, samples should be collected at the site and archived to allow potential future analyses.

Literature Cited

Alberta Biodiversity Monitoring Institute. 2015. Spatial distribution, habitat associations, responses to human footprint, and predicted relative abundance distributions for 2287 species in Alberta. Retrieved from http://species.abmi.ca/pages/species.html. Accessed November 2015.

Alberta Environmental Protection and Enhancement Act. 2010. Alberta Environmental Protection and Enhancement Act Revised Statutes of Alberta 2000 Chapter E-12. Retrieved from http://www.qp.alberta.ca/documents/Acts/E12.pdf. Accessed November 2015.

Alberta Environment and Parks. 2015. Lower Athabasca regional plan strategies. Retrieved from http://esrd.alberta.ca/focus/cumulative-effects/cumulative-effects-management/management-frameworks/documents/LARP-FactSheet-Strategies-Feb13-2014.pdf. Accessed November 2015.

Bailey, R.C., Kennedy, M.G., Dervish, M.Z. and Taylor, R.M. 1998. Biological assessment of freshwater ecosystems using a reference condition approach: comparing predicted and actual benthic invertebrate communities in Yukon streams. Freshwater Biology 39: 765–774.

Borkenhagen, A. and Cooper, D.J. 2015. Creating fen initiation conditions: a new approach for peatland reclamation in the oil sands region of Alberta. Journal of Applied Ecology 53: 550–558. doi: 10.1111/1365-2664.12555.

Burton, C., Huggard, D., Bayne, E., Schieck, J., Solymos, P., Muhly, T., Farr, D. and Boutin, S. 2014. A framework for adaptive monitoring of the cumulative effects of human footprint on biodiversity. Environmental Monitoring and Assessment 186: 3605–3617. doi: 10.1007/s10661-014-3643-7.

Canadian Association of Petroleum Producers (CAPP). 2013. About Canada's oil sands. Retrieved from http://www.capp.ca/publications-and-statistics/publications/228182. Accessed June 2016.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., and Jäger, J . 2003. Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences of the United States of America. 100: 8086–8091.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., and Jäger, J. 2002. Salience, Credibility, Legitimacy and Boundaries: Linking Research, Assessment and Decision Making. KSG Working Papers Series RWP02-046. Retrieved from http://ssrn.com/abstract=372280. Accessed June 2016.

CH2MHill. 2013. Operational Regional Wetlands Monitoring Program. Final report to Suncor Energy Inc., Imperial Oil Resources Ltd., Shell Canada Energy, Total E&P Canada Ltd., and Syncrude Canada Ltd. Calgary, Alberta. 101 pages + appendices.

Ciborowski, J.J.H., Grgicak-Mannion, A., Kang, M., Rooney, R., Zeng, H., Kovalenko, K., Bayley, S.E., Foote, A.L. 2012. Development of a Regional Monitoring Program to Assess the Effects of Oil Sands Development on Wetland Communities. Final Report for the Cumulative Environmental Management Association (CEMA). 286 pages.

Ciborowski, J.J.H., Johnson, L.B., Tomal, J.H., Fung, K., Bhagat, Y., and Zhang, J. 2010. Calibrating biological indicators against the Reference-Degraded Continuum: Examples from Great Lakes biota. Bulletin of the North American Benthological Society 27: 45–46.

Cumulative Environnemental Management Association. 2012. Development of a regional monitoring program to assess the effects of oil sands development on wetland communities. Retrieved from http://library.cemaonline.ca. Accessed November 2015.

de Groot, R.S., Wilson, M.A. and Boumans, R.M.J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41 :393–408.

Elvin, S.S. and Fraser, G.S. 2012. Advancing a national strategic environmental assessment for the Canadian offshore oil and gas industry with special emphasis on cumulative effects. Journal of Environmental Assessment Policy & Management 14: 1250015. doi: 10.1142/S1464333212500159.

Foote, L. 2012. Threshold considerations and wetland reclamation in Alberta's mineable oil sands. Ecology and Society 17: 35–46.

Ford, D.E. 2000. Scientific Method for Ecological Research. Cambridge University Press. Cambridge, UK.

Gotelli, N.J. and Ellison, A.M. 2004. A primer of ecological statistics. Sinaur Associates Inc. Sunderland MA, USA.

Haughland, D.L., Hero, J-M., Schieck, J., Castley, J.G., Boutin, S., Solymos, P., Lawson, B.E., Holloway, G. and Magnusson, W.E. 2010. Planning forwards: biodiversity research and monitoring systems for better management. Trends in Ecology & Evolution 25: 199–200.

Hegmann, G., Cocklin, C., Creasey, R., Dupuis, S., Kennedy, A., Kingsley, L., Ross, W., Spaling, H. and Stalker, D. 1999. Cumulative Effects Assessment Practitioners Guide. Prepared by AXYS Environmental Consulting Ltd. and the CEA Working Group for the Canadian Environmental Assessment Agency, Hull, QB, Canada.

Jean, C., Schrag, A.M., Bennetts, R.E., Daley, R., Crowe, E.A., and O'Ney, S. 2005. Vital Signs Monitoring Plan for the Greater Yellowstone Network. Bozeman MT: National Park Service, Greater Yellowstone Network.

Kangas, A. and Maltamo, M. 2006. Forest inventory, methodological applications. Springer, Dordrecht, Netherlands.

Kovalenko, K.E., Ciborowski, J.J.H, Daly, C., Dixon, G., Farwell, A.J., Foote, L., K.A. Frederick, J.M., Gardner, J.M., Costa, J.M., Kennedy, K.D., Liber, K., Roy, M.C., Slama, C.A. and Smits, J.E.G. 2013. Food web structure in oil sands reclaimed wetlands. Ecological Applications 23: 1048–1060.

Lindenmayer, D.B., and Likens, G.E. 2009. Adaptive monitoring: A new paradigm for long-term research and monitoring. Trends in Ecology & Evolution 24: 482–486.

Magnusson, W.E., Costa, F., Lima, A., Baccaro, F., Braga-Neto, R., Romero, R.L., Menin, M., Penha, J., Hero, J-M., and Lawson, B.E. 2008. A program for monitoring biological diversity in the Amazon: An alternative perspective to threat-based monitoring. Biotropica 40: 409–411.

Mitsch, W.J., J.G. Gosselink. 2011. Wetlands. John Wiley and Sons. Hoboken, New Jersey. USA.

Nichols, J.D. and Williams, B.K. 2006. Monitoring for conservation. Trends in Ecology & Evolution 21: 668–673.

Ramalho, C.E., Laliberté, E., Poot, P. and Hobbs, R.J. 2014. Complex effects of fragmentation on remnant woodland plant communities of a rapidly urbanizing biodiversity hotspot. Ecology 95: 2466–2478.

Rooney, R.C. and Bayley, S.E. 2011. Setting appropriate reclamation targets and evaluating success: aquatic vegetation in natural and post-oil-sands mining wetlands in Alberta, Canada. Ecological Engineering 37: 569–579.

Rooney, R.C. and Bayley, S.E. 2012. Development and testing of an index of biotic integrity based on submersed and floating vegetation and its application to assess reclamation wetlands in Alberta's oil sands area, Canada. Environmental Monitoring and Assessment 184: 749–761.

Saunders, D., Hobbs, R. and Margules, C. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18–32.

Slattery, S (Ducks Unlimited Canada). 2016. Waterfowl of the Boreal Forest. Retrieved from http://www.ducks.org/conservation/Western-Boreal-Forest. Accessed June 2016.

Vitt, D.H., L.A. Halsey, M. Thormann and T. Martin. 1996. Peatland Inventory of Alberta. Prepared for the Alberta Peat Task Force, National Center of Excellence in Sustainable Forest Management, University of Alberta, Edmonton.

Wintel, B.A., Runge, M.C., Bekessy, S.A. 2010. Allocating monitoring effort in the face of unknown unknowns. Ecology Letters 13: 1325–1337. doi:10.11 1 1/j. 1461-0248.2010.01514.x.

Zedler, J. B. and Callaway, J.C. 1999. Tracking Wetland Restoration: Do mitigation sites follow desired trajectories? Restoration Ecology 7: 69–73. doi: 10.1046/j.1526-100X.1999.07108.x.

Appendix 1 – Guiding Principles in Detail

The wetland monitoring program for the Oil Sands Region (OSR) should have the following characteristics:

Relevance and Timeliness

- The program provides information to support the main current and reasonably foreseeable monitoring needs of the industry, government, and other stakeholders.
- Information derived from the wetland monitoring program is timely and appropriate to the question being addressed.

Scalability

- At the regional scale the program uses a consistent set of indicators and a consistent sampling effort. It has local program objectives to monitors a broad set of indicators at the core, and a more extensive set of variables for specific situations and monitoring questions as and if required.
- It uses standardized protocols and methods to ensure that the information can be used by various stakeholders, for different purposes, in various landscape settings, and at various spatial scales (e.g., local to sub-regional and regional).
- It optimizes the use of covariates derived from GIS/geospatial layers (e.g., digital elevation models). To project stressor-response models to either a different landscape setting or to simulated future landscapes, the important covariates are mapped throughout the target landscape(s)
- It allows incorporating additional or complementary monitoring sites and variables over time.

Cost-effectiveness

- It ensures that protocols, methods, data, analysis and results are open access and publicly shared.
- It avoids duplication of monitoring efforts between stakeholders. Common monitoring sites and variables can be used (at the extent relevant) by various stakeholders to fulfil their monitoring needs.
- It uses protocols, methods (e.g., field versus remote sensing), sampling locations, and variables to monitor in light of their relevancy and expected balance of benefits and associated costs.
- It adopts a multi-level monitoring approach where appropriate monitoring and management actions are prompt once change (i.e. departure from natural variability) has been detected.
- It uses data, protocols, methods, and results (at the extent relevant) from existing monitoring programs to leverage resources.

Transparency and Accessibility

- It ensures free and open-access to protocols, methods, QA/QC data, initial analysis and results.
- It shares the geographic location of sampling sites.
- It uses indicators that are anticipatory and diagnostic to forecast impending wetland degradation far enough in advance that corrective actions can be taken before wetlands become significantly altered.
- It shares information efficiently and quickly to ensure that management actions can be taken before adverse change in wetland condition cannot be easily mitigated.

Scientific Robustness

- It is preceded by a pilot program during which protocols, methods, analyses, etc. are tested, refined and validated. Potential indicators to be monitored are identified and tested.

- It detects and differentiates change caused by anthropogenic activities from change caused by natural drivers.
- It requires baseline data to provide adequate definition to the natural range of variability and statistical power to detect meaningful change.
- It supports and is supported by research.
- Its sampling design allows maximizing the signal/noise ratio by focusing the monitoring on variables that respond strongly to stressors and that can be measured with high accuracy and precision.
- When modeling wetland condition, it uses covariates and repeated measures to control noise (i.e., natural spatial and temporal variability of wetlands).
- It optimizes sample size to enhance the statistical power to detect change.

Appendix 2 – Potential Management Response

Throughout our consultation process, stakeholders consistently voiced concern and confusion over the role that the integrated wetland monitoring program will play in regulatory and policy decision-making. This appendix is an attempt to scope the role of the program in a broader natural resource decision-making process. Depending on the monitoring information provided, mitigative actions may or may not be adopted. When actions are required, potential options may be reviewed and evaluated so that the most sensible action is implemented. Once mitigative actions have been implemented, information collected through monitoring is used to verify the efficacy of such actions. Reporting on the state of wetlands is provided on a regular basis and is an opportunity to inform stakeholders and resource managers on the progress towards achieving the wetland management objectives.

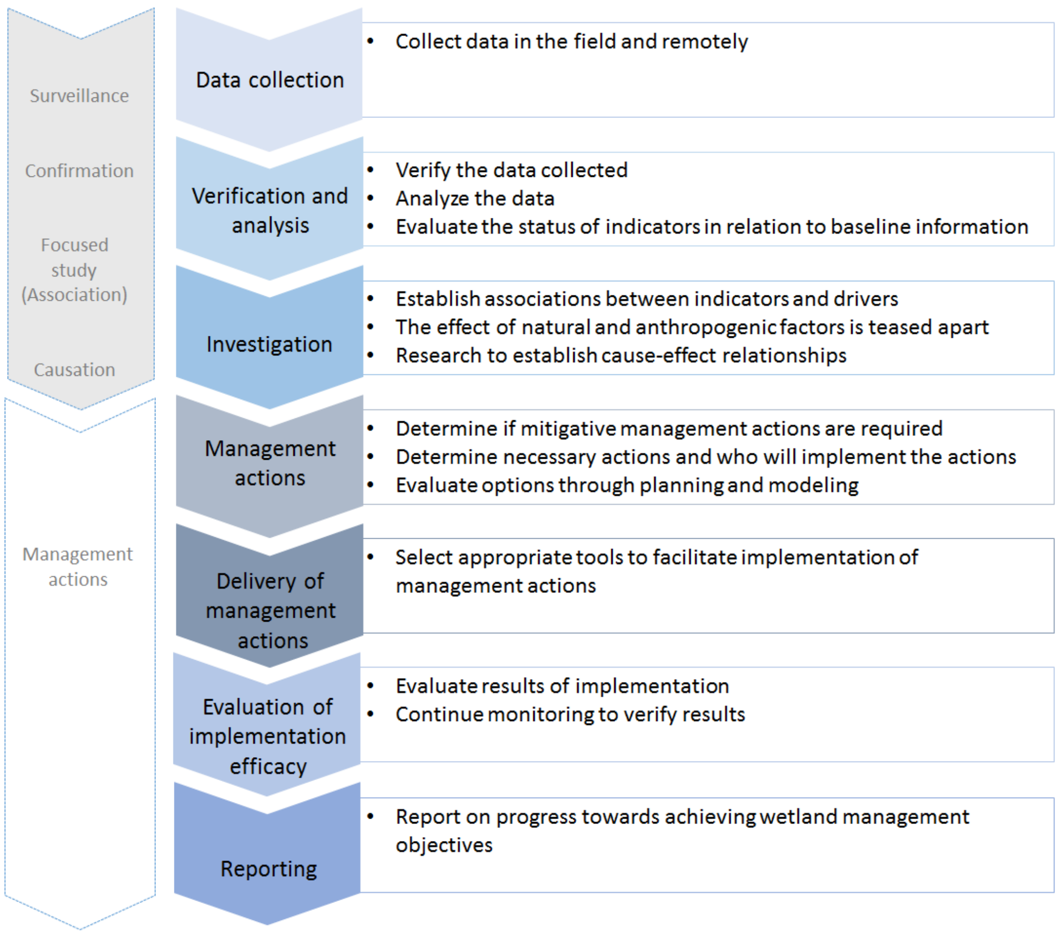

Figure A2- 1: Potential management response process (adapted from the draft for the Lower Athabasca Region Biodiversity Management Framework [31]).

---

[31] Government of Alberta. Draft for the Lower Athabasca Region Biodiversity Management Framework. 2014. V.1.0. https://banister.ab.ca/larbmfsurvey/DRAFT_LARP_BMF.pdf

Appendix 3 – Detailed Monitoring Questions

For each of the main anthropogenic activities occurring in the region, a potential suite of key drivers and associated stressors was identified and prioritized[32]. Based on the prioritized drivers and stressors, a non-exhaustive list of monitoring questions was developed for Goal 1 (Local) and Goal 2 (Regional). These prioritized questions informed the selection of relevant indicators (Appendix 3).

Goal 1 (Local)

1. Oil Sands* – *Mining

Are activities related to oil sands mining changing the condition of wetlands in and adjacent to mining areas?

1. Is aquifer, surface, and shallow groundwater dewatering affecting wetlands?
2. Are emissions of airborne pollutants affecting wetlands?
3. Is groundwater seepage and runoff affecting wetlands?
4. Are land disturbances causing complete or partial removal of wetlands (direct effect)?
5. Are land disturbances indirectly affecting wetlands?

2. Oil and Gas – In Situ

Are activities related to oil and gas exploration changing the condition of wetlands within and adjacent to oil and gas facilities?

1. Are land disturbances indirectly affecting wetlands?
2. Are air emissions affecting wetlands?
3. Are linear disturbances leading to surface and sub-surface hydrological changes indirectly affecting wetlands?
4. Are land disturbances causing complete or partial removal of wetlands (direct effect)?
5. Are major and minor spills affecting wetlands?
6. Is vegetation removal/clearing in catchment affecting wetlands?

3. Forestry

Are activities related to forestry changing the condition of wetlands adjacent to forest management areas?

1. Are land disturbances indirectly affecting wetlands?
2. Are linear disturbances leading to surface and sub-surface hydrological changes indirectly affecting wetlands?
3. Is vegetation removal/clearing in catchment affecting wetlands?

4. Agriculture

Are activities related to agriculture changing the condition of wetlands adjacent to agricultural areas?

1. Are land disturbances indirectly affecting wetlands?

---

[32] Refer to the supporting document *Stressors and Indicators of Wetland Change in Alberta's Oil Sands Region – Potential for Use in Wetland Monitoring* for further details about the rationale behind each monitoring question and how indicators relate to these questions.

2. Are land disturbances causing complete or partial removal of wetlands (direct effect)?
3. Is drainage affecting wetlands?
4. Is runoff from land use affecting wetlands?

5. Urbanization

Are activities related to urbanization changing the condition of wetlands adjacent to urban areas?

1. Are land disturbances indirectly affecting wetlands?
2. Are air emissions affecting wetlands?
3. Are land disturbances causing complete or partial removal of wetlands (direct effect)?
4. Are linear disturbances causing surface and sub-surface hydrological changes?
5. Is runoff from land use affecting wetlands?

Goal 2 (Regional)

Impacts to wetland may be caused by different types of stressors related to the same anthropogenic activity (or sector). In this context, the cumulative effects component of the monitoring program aims to answer the following questions:

1. Are oil sands mining-related activities affecting the condition of wetlands?
2. Are oil and gas (*in situ*)-related activities affecting the condition of wetlands?
3. Are forestry-related activities affecting the condition of wetlands?
4. Are agriculture-related activities affecting the condition of wetlands?
5. Are urban development related activities affecting the condition of wetlands?

Impacts to wetland may be caused by the same type of drivers related to different anthropogenic activities. In this context, the cumulative effects component of the monitoring program aims to answer the following questions:

1. Is hydrological alteration affecting wetlands?
2. Are emissions of airborne pollutants affecting wetlands?
3. Is surface water seepage and runoff affecting wetlands?
4. Are land disturbances causing complete or partial removal of wetlands (direct effect)?
5. Are land disturbances indirectly affecting wetlands?

Appendix 4 – Criteria for Indicator Selection

Indicators must be meaningful to the goals of the program and practical to monitor. We developed criteria to help aid in the selection of indicators for both Goal 1 and Goal 2. These criteria where derived through the review of wetland literature, indicator selection literature, stakeholder engagement literature, and policy documents such as the Convention on Biological Diversity Aichi Targets (2011–2020). Indicators for the integrated wetland monitoring program where prioritized based on the following criteria:

Responsive to Anthropogenic Activity:

- Sensitive to main anthropogenic activities in the region;
- Robust at detecting an impact;
- Special consideration is given to indicators that are responsive to multiple anthropogenic drivers;
- Special consideration is given to indicators that are known to respond to specific drivers of interest.

Relevant to Stakeholders:

- The indicators were selected considering the outcomes of the engagement process with wetland experts and stakeholders;
- Associated with the needs of a wide range of stakeholders;
- Response to change in land-use is easily interpretable;
- Methods of sampling and analysis are easily explainable and the results are easily conveyed to managers and general public.

Ecologically Relevant:

- Relevant to the classes of wetlands present in the OSR;
- Characterized by a relatively narrow range of natural variability over time and space, or their variability is sufficiently understood;
- Factors (covariates) influencing the indicators' variability can be isolated and measured;
- Indicators were prioritized based on their contribution to information as part of a suite of indicators.

Practical and Cost-effective:

- Methods for collecting relevant information about the indicators in the field or remotely[33] are cost-effective;
- Methods for collecting relevant information about the indicators in the field or via remote sensing are appropriately accurate and precise;
- Selected considering if they were representing a part of an existing datasets to enable/continue long-term wetland monitoring;
- Characteristics are relatively easy to analyze.

---

[33] Refer to the supporting document - *Review of Remote Sensing Methods for Monitoring Wetlands in Northeastern Alberta* for further details about existing methods to collect information remotely and estimated range of costs associated with the acquisition of remotely sensed data.

Indicators that are recommended in this report were identified by applying these criteria throughout our project and by reviewing previously published literature/resources including the CH2MHill[34] and Ciborowski et al. (2012)[35] reports.

[34] CH2MHill. 2013. Operational Regional Wetlands Monitoring Program. Final report to Suncor Energy Inc., Imperial Oil Resources Ltd., Shell Canada Energy, Total E&P Canada Ltd., and Syncrude Canada Ltd. Calgary, Alberta. 101 pages plus appendices.
[35] Ciborowski, J.J.H., A. Grgicak-Mannion, M. Kang, R. Rooney, H. Zeng, K. Kovalenko, S.E. Bayley, A.L. Foote. 2012. Development of a Regional Monitoring Program to Assess the Effects of Oil Sands Development on Wetland Communities. Final Report for the Cumulative Environmental Management Association (CEMA). 286 pages.

Appendix 5 – Recommended Indicators for Each Monitoring Option

In this Appendix, we recommend indicators that would make up a program for all three monitoring program options (Basic, Robust, and Augmented; Table A5-1 below)[36].

Table A5 - 1: Proposed indicators for the integrated wetland monitoring program. The indicators are arrayed against three monitoring options; "X" identifies suggested indicators for monitoring each option.

Variables	Type of data	Basic	Robust	Augmented
Vascular plant				
Species occurrence	Field	X	X	X
Species abundance	Field	X	X	X
Productivity	Remote/field			X
Other, e.g., rare species, medicinal species				X
Macro-invertebrate[37]				
Species occurrence	Field		X	X
Species abundance	Field		X	X
Moss and lichen[38]	Field			
Species occurrence	Field		X	X
Species abundance	Field		X	X
Health	Field		X	X
Wildlife				
Toxicity	Field			X
Taxa of interest (bird, mammal, amphibian, etc.)	Field			X
WATER				
Water quality				
Routine chemistry, e.g.,				
Temperature	Field	X	X	X
pH and alkalinity	Field	X	X	X
Salinity	Field	X	X	X
Conductivity	Field	X	X	X
Dissolved Oxygen Concentration (DO)	Field	X	X	X

[36] Refer to the supporting document *Stressors and Indicators of Wetland Change in Alberta's Oil Sands Region – Potential for Use in Wetland Monitoring* for further details about the indicators and the classes of wetland in which they should be monitored.
[37] If macro-invertebrates and planktons are monitored in open-water wetlands, fish occurrence and abundance may need to be assessed as a covariate.
[38] Although moss and lichen occurrence and abundance were not identified as potential indicators in the supporting document *Stressors and Indicators of Wetland Change in Alberta's Oil Sands Region – Potential for Use in Wetland Monitoring,* these variables were included based on the needs expressed by AER.

Variables (continued)	Type of data	Basic	Robust	Augmented
Redox potential	Field	X	X	X
Additional variables e.g., TDS, TSS, etc.	Field			X
Water transparency	Field	X	X	X
Nutrients e.g.,	Field			
Total Nitrogen (TN)	Field	X	X	X
Total Phosphorus (TP)	Field	X	X	X
Sulfur (S)	Field		X	X
Carbon/Nitrogen ratio in peat	Field		X	X
Additonal metrics e.g.s, Total Carbon (TC), Dissolved Organic Carbon (DOC), etc.)	Field			X
Other				
Isotopes				X
Mercury methylation	Field		X	X
Hydrocarbons	Field		X	X
Ions e.g.,				
Na+, K+, Ca2+, Mg2+	Field	X	X	X
SO42-, Cl-, CO32-, HCO3	Field	X	X	X
Metals e.g.,				
Total, Iron (Fe), Aluminium (Al),	Field	X	X	X
Additional metals, e.g., Boron (B), Manganese (Mn), etc.	Field			X
Phytoplankton				
Chlorophyll-a (Chl-a)	Field		X	X
Water quantity				
Depth to water table	Field	X	X	X
Water depth and amplitude	Field	X	X	X
Water flow				X
Water connectivity				X
SOIL				
Soil quality				
Moisture	Field	X	X	X
Bulk density	Field	X	X	X
Texture	Field	X	X	X
Type	Field	X	X	X
Depth	Field	X	X	X
Polycyclic aromatic hydrocarbon concentration	Field	X	X	X
Hydrocarbons	Field	X	X	X
Metals, e.g.,	Field			
Total, Fe, Al,	Field	X	X	X
Additional metals e.g., Boron, Manganese, etc.				X
Nutrients, e.g.,	Field			
Total Nitrogen (TN)	Field	X	X	X
Total Phosphorus (TP)	Field	X	X	X

Variables (continued)	Type of data	Basic	Robust	Augmented
Sulfur (S)	Field		X	X
Additional metrics, e.g., Total Carbon (TC), Dissolved Organic Carbon (DOC), etc.)	Field			X
Other				
Biocides	Field		X	X
Soil quantity				
Peat accumulation	Field	X	X	X
WETLAND AREA AND LAND USE				
Wetland				
Total area	Remote	X	X	X
Area of vegetative zone (including open water)	Remote	X	X	X
Land use e.g.,				
% disturbed land	Remote	X	X	X
Linear density	Remote	X	X	X
Cumulative wetland loss	Remote		X	X

Table A5 - 2: Covariates[39] to monitor for the monitoring program.

Covariates	Type of Data
Geographic location	Remote
Geographic distribution	Remote
Wetland classification	Remote/field
Year of sampling	Remote
Annual climate	Remote
Natural region or sub-region	Remote
Watershed order	Remote
Coarse soil types	Remote
Coarse vegetation types	Remote
Surficial geology	Remote
Parent material	Remote
Beaver presence	Remote/field
Land-use type, occurrence, and abundance in or adjacent to wetland	Remote

[39] These covariates should be measured under all three monitoring options (i.e., Basic, Robust, and Augmented).

Appendix 6 – The Role of Scientific Research

Scientific research will factor significantly in the operation of the integrated wetland monitoring program in two ways:

1. **Continuous Improvement** – the monitoring system needs to benefit from advancements in research and technology related to the business of wetland monitoring. In addition, research is necessary to develop the fundamentals of the monitoring program including its sampling design and methods, protocols, and analysis. Variables will be validated through research. The most certain means of ensuring that the monitoring system is continuously improving is to maintain systemic links with academia and research organizations.
2. **Applied Research** – the monitoring system will require research to answer causation-related questions. This research may include highly controlled before-after, control-impact research programs or retrospective research approaches. Key assumptions in statistical or management models may also need to be validated before management action is taken. University, government or industry applied research programs can be cooperatively designed to identify these gaps in knowledge.

Appendix 7 – List of Supporting Documents

Recommendations put forward in this report are supported by several technical documents that were created as part of the overall project. The following technical reports are available as part of the project deliverables.

- *Identifying the Scope and Objectives of the Wetland Monitoring Program – A Three-Phased Stakeholder Engagement Process.*
- *Wetland Management and Monitoring Needs – A Review of Alberta's Environmental Legislation, Regulations and Policies Related to Wetland Management.*
- *Review of Wetland Field Monitoring Programs in Northeastern Alberta.*
- *Review of Remote Sensing Methods for Monitoring Wetlands in Northeastern Alberta.*
- *Monitoring Designs to Assess Cumulative Effects and Stressor-Response Relationships.*
- *Stressors and Indicators of Wetland Change in Alberta's Oil Sands Region – Potential for Use in Wetland Monitoring*

In addition, we drew significantly from previous work on this topic including previously published literature/resources, such as the CH2MHill and Ciborowski et al. (2012) reports, and engaged with key representatives from the AER's EPEA Oil Sands Mine Wetland Monitoring Program Working Group throughout the process.

Appendix 8 – Letter from AER to AEMERA and EPEA Oil Sands Mine Wetland Monitoring Program Recommendation Report

Edmonton Office
4th Floor, Twin Atria Building
4999 – 98 Avenue
Edmonton, Alberta T6B 2X3
Canada

www.aer.ca

File No. 4101-00000026-07-Wetlands
File No. 4101-00000094-07-Wetlands
File No. 4101-00046586-07-Wetlands
File No. 4101-00151469-07-Wetlands
File No. 4101-00020809-07-Wetlands
File No. 4101-00149968-07-Wetlands
File No. 4101-00228044-07-Wetlands
File No. 4101-00153125-07-Wetlands

April 1, 2016

BY E-MAIL ONLY

Fred Wrona, PhD
Vice President and Chief Scientist
Alberta Environmental Monitoring, Evaluation and Reporting Agency
10th Floor, 9888 Jasper Avenue NW
Edmonton, AB T5J 5C6

E-mail: fred.wrona@aemera.org

Re: Recommendations for AEMERA's Regional Wetland Monitoring Program to meet the following EPEA Wetland Monitoring conditions:

- Syncrude Mildred Lake and Aurora EPEA Approval 26-02-00, as amended, Wetland Monitoring Plan, Conditions 6.1.66-6.1.68;
- Suncor Base Plant EPEA Approval 94-02-00, as amended, Wetland Monitoring Plan, Conditions 6.1.70-6.1.72;
- Imperial Kearl EPEA Approval 46586-00-00, as amended, Wetland Monitoring Plan, Conditions 6.1.66-6.1.68;
- Suncor Fort Hills EPEA Approval 151469-01-00, as amended, Wetland Monitoring Plan, Conditions 6.3.7-6.3.11;
- Shell Muskeg River Mine EPEA Approval 20809-01-00, as amended, Wetland Monitoring Plan, Conditions 6.1.66-6.1.68;
- CNRL Horizon Mine EPEA Approval 149968-01-00, as amended, Wetland Monitoring Plan, Conditions 6.3.7-6.3.11;
- Total Joslyn Mine EPEA Approval 228044-00-00, as amended, Wetland Monitoring Plan, Conditions 6.4.20-6.4.22; and
- Shell Jackpine Mine EPEA Approval 153125-00-00, as amended.

Dear Dr. Wrona,

The Alberta Energy Regulator (AER) requests the Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA) develop and implement a wetland monitoring program as part of the Oil Sands Environment Monitoring Program in the 2016-2017 Work Plan, and going forward. AEMERA has provincial responsibility for establishing the Oil Sands Environmental Monitoring Program. Under the EPEA approvals, AER requires oil sands mine operators to develop and implement a wetland monitoring program, which includes, at a minimum, all of the following:

(a) a plan to monitor natural wetlands for natural variability;

(b) a plan to determine and monitor the potential effect of dewatering and mine development on wetland communities; and

inquiries 1-855-297-8311
24-hour emergency 1-800-222-6514

(c) corrective measures, where appropriate, to protect affected wetland communities.

Operator compliance of these requirements, which has been outstanding since 2008, is considered a high priority item by AER. Under the '*Oil Sands Environmental Monitoring Program Regulation',* if an oil sands company holds a subsisting approval or an active application, they must participate in the Oil Sands Environmental Monitoring Program. A participant who has paid fees associated with participation in the Oil Sands Environmental Monitoring Program is deemed to have complied with the conditions or portions of conditions, in the approval that (a) are the subject matter of the assessment, and (b) are set out in the applicable approved annual monitoring plan. AER requests AEMERA develop and implement a regional oil sands wetland monitoring program in 2016-2017 and going forward, which meets the requirements of the aforementioned EPEA approval conditions, or portions of the conditions.

To expedite the development of a regional oil sands wetland monitoring program, AER initiated an EPEA Oil Sands Mine Wetland Monitoring Program Working Group in December 2015. The working group was composed of representatives from AER, AEMERA, AEP, CAPP and COSIA. The goals of the working group were to develop an Oil Sands Wetland Monitoring Program that will meet EPEA approval conditions, can be implemented quickly, and aligns with various agency's mandates and resources. More specifically, the working group sought to define key EPEA oil sands mine wetland monitoring program objectives, key questions, a monitoring approach and design to address the key questions, and the key drivers, stressors and indicators that will form a core wetland monitoring program. Key foundation documents were reviewed including the CEMA Wetland Monitoring Framework Report (2012), the CH2M Hill Joint Industry Wetland Monitoring Proposal (2013), and the JOSM Peace-Athabasca Delta Wetland Monitoring Program (currently under the Oil Sands Environmental Monitoring Program). Other key provincial government policies, management frameworks and monitoring programs in the oil sands region, were considered for alignment to the extent appropriate and feasible (e.g. Alberta Wetland Policy, LARP Biodiversity Framework wetland indicators). The working group presented its findings and recommendations at a workshop hosted by AER (February 29, 2016) and sought broader input from their respective agencies and affiliations. This input was incorporated into the EPEA Oil Sands Mine Wetland Monitoring Program Recommendations Report (Appendix A). AER respectfully submits this recommendations report to AEMERA for consideration in the development of its Oil Sands Environmental Monitoring Program 2016-2017 Work Plan.

AER requests a letter from AEMERA describing its Oil Sands Environmental Monitoring Program 2016-2017 Work Plan for wetland monitoring, which recommendations, or portions of the recommendations, of the EPEA Oil Sands Mine Wetland Monitoring Program Recommendations Report will be adopted (Appendix A); and which EPEA wetland monitoring program approval conditions, or portions of the conditions, will be met. A letter of response is requested by April 21, 2016.

If you have any questions, please contact Danielle Cobbaert at 780-814-0864.

Sincerely,

Terence Ko, P.Eng.
Manager, EPEA and Water
Mining Authorizations

inquiries 1-855-297-8311
24-hour emergency 1-800-222-6514

cc: Danielle Cobbaert, AER
Richard Chabaylo, AER
Monique Dubé, AER
Ken Bannister, AER
Pat Marriot, AER
Agnes Wajda-Plytta, AER
Rod Hazewinkel, AEP
Marsha Trites-Russell, AEP
Terry Abel, CAPP
Kelly Munkittrick, COSIA

March 28, 2016

This report was developed by a working group was composed of representatives from AER, AEMERA, AEP, CAPP and COSIA. The goals of the working group were to develop an Oil Sands Wetland Monitoring Program that will meet EPEA approval conditions, can be implemented quickly, and aligns with various agency's mandates and resources. More specifically, the working group sought to define key EPEA oil sands mine wetland monitoring program objectives, key questions, a monitoring approach and design to address the key questions, and the key drivers, stressors and indicators that will form a core wetland monitoring program. Key foundation documents were reviewed including the CEMA Wetland Monitoring Framework Report (2012), the CH2M Hill Joint Industry Wetland Monitoring Proposal (2013), and the JOSM Peace-Athabasca Delta Wetland Monitoring Program (currently funder the Oil Sands Environmental Monitoring Program). Other key provincial government policies, management frameworks and monitoring programs in the oil sands region, were considered for alignment to the extent appropriate and feasible (e.g. Alberta Wetland Policy, LARP Biodiversity Framework wetland indicators). The working group presented its findings and recommendations at a workshop hosted by AER (February 29, 2016) and sought broader input from their respective agencies and affiliations. AER respectfully submits this recommendations report to AEMERA for consideration in the development of its Oil Sands Environment Monitoring Program 2016-2017 Work Plan.

Interpretation of the EPEA Wetland Monitoring Conditions

Environmental Protection and Enhancement Act (EPEA) approvals for the oil sands mines include requirements for a Wetland Monitoring Program which shall include, at a minimum, all of the following:

(a) a plan to monitor natural wetlands for natural variability;

(b) a plan to determine and monitor the potential effect of dewatering and mine development on wetland communities; and

(c) corrective measures, where appropriate, to protect affected wetland communities.

The overall goal of these conditions is to address concerns raised in Environmental Impact Assessments (EIA) and ensure that deleterious impacts on valued wetland ecosystem components are minimized.

First and foremost, these EPEA conditions require an effect-based wetland monitoring program that will assess a causal relationship between key drivers associated with mine development and wetland communities. The primary response of concern in reference to biological communities is interpreted as the biological endpoints, with environmental variables important for helping to interpret the driver – stressor- response pathway. Thus the monitoring program should be able to address the question – Are the oil sands mines causing an effect on wetlands?

An understanding of natural variability is critical for understanding whether effects are meaningful as well as whether they are due to mine development versus other confounding factors including key natural drivers (e.g. climate variability, topography). Understanding natural variability requires an understanding of both spatial variability (how does wetland extent, class and distribution in the oil sands region vary by differences in climate, surficial geology, soils, topography?) and temporal variability (how do natural wetlands vary over time?).

Finally, if a meaningful effect from oil sands mines development on wetlands is detected, the monitoring program should be able to evaluate the cause of the effect and identify potential corrective measures to help reverse effects and protect affected wetland communities. Thus, the monitoring program as a whole should be able to distinguish between effects at the individual operator-level and the wider sector-level, as well as distinguish between various potential driver – stressor – responses pathways.

Tiered Effect-Based Monitoring Approach

To develop a basic monitoring program that can assess if oil sands mine development is causing an effect on wetlands, and where effects are detected then identify potential corrective measures, a tiered effect-based program is recommended. A tiered monitoring approach with the following tiers, sampling frequency and questions is recommended:

- Surveillance – Basic or core wetland monitoring program. Regular frequency. Is there an effect?
- Confirmation – Assess reference site adequacy. More frequent sampling, but minimal required for confirmation of effects. Can the effect be confirmed?
- Extent and magnitude (Focused monitoring). Sample more stations and indicators to delineate the extent of effects, and sample more indicators to assess the magnitude of effects to various ecological endpoints. What is the extent and magnitude of the effects?
- Investigation of cause (IOC) – Research-oriented. What is the cause of the effect?
- Investigation of solutions (IOS). What are the potential solutions?

Recommended Key Questions and Preliminary Studies

The development of a basic wetland monitoring program to meet the EPEA conditions should focus on the key drivers associated with oil sands mines most likely to cause effects. Most wetlands within lease boundaries will be lost due to mine disturbance, thus a focus on understanding drivers likely to cause effects to adjacent natural wetlands is recommended. The following key monitoring questions and initial monitoring studies are based on the current state of knowledge of these key driver-stressor-response relationships based on research studies and expert opinion.

1) A) Is hydrologic alteration from oil sands mines causing an effect on the ecological condition of the most dominant wetland classes adjacent to the mine lease boundaries compared to the range of natural variability of the reference conditions?

   This question could be addressed through the following preliminary studies:

i) A first pass regional, remote sensing study to assess the potential effects of hydrologic alteration from mines on wetland condition. The study should test the hypothesis that wetlands located closer to the mines will show changes to vegetation community composition and productivity (biologic response) compared to sites located further away as a consequence of decreased water table depth and decreased surface water and groundwater inputs (stressors associated with hydrologic alteration). This study would focus on determining whether effects are detectable using remote sensing information with supplemental ground truth results. Initially, the study should focus on sites most likely affected by hydrologic alterations from the mines (i.e. wetlands closest to the mine pits, wetlands most sensitive to hydrologic alteration, site selection informed by operator observations of effects). If effects are detected, this study could be expanded to examine the extent and magnitude of effects (e.g. 10m, 100m, 500m, 2km, 10km etc.).

Potential remote sensing indicators* are:

- Water level using Lidar imagery,
- Hyperspectral imagery to assess vegetation condition and community types, which may also be used to assess wetland class, and wetland extent.

*Limitations of remote sensing may be a factor affecting the success of this study.

Field validation and ground truth results will be needed. Potential field indicators could be:

- Water table depth, flow
- Stable isotopes (use to identify primary water sources - SW, GW, ppt; residence time),
- Water quality (e.g. EC, salts, TSS, TOC, alkalinity, DOC, nutrients, pH),
- Vegetation community quadrats, and
- Wetland delineation and classification.

ii) A first pass local, mechanistic field study focused on establishing the extent and magnitude of the potential hydrologic alteration gradient associated with oil sands mines on wetlands adjacent to oil sands mines could be determined through:

- A workshop –

  - What do we know about the influence of mine development on surface water and ground water alteration gradients (extent and magnitude) based on current SW and GW monitoring (at mine fencelines and otherwise), expert observation, and hydrology or hydrogeology models?

  - Which wetlands are most likely to be affected by hydrologic or hydrogeologic alteration from oil sands mines (i.e. identify potential sites for field study)?

- What remote sensing information is available to assess hydrology and vegetation at the fenceline? (ties to remote sensing study)
- People to invite to the workshop:
  - (i) Mine operations staff - hydrologists, hydrogeologists and environmental teams.
  - (ii) Academics – GW hydrologists, hydrogeologists (e.g. Kevin Devito, Carl Mendoza, Jonathan Price).

- A local scale hydrologic field study likely needed to scope the gradient of hydrologic alteration associated with a mine to evaluate the potential magnitude of the stressor (e.g. 10m, 100m, 500m, 2km, 10km etc.)

1B) Is there an effect of aerial deposition from oil sands mines on wetlands located in deposition pathways/ plumes on the ecological condition of the most dominant wetland classes compared to the range of natural variability of reference conditions?

This question could be addressed through the following preliminary studies:

i) A focused workshop on oil sands effects aerial deposition driver and wetland ecosystem response monitoring program to synthesize research and monitoring results, and recommend a core EPEA oil sands mine wetland monitoring program to address the above key monitoring question. Effects from aerial deposition associated with oil sands mine development on the biological response of wetlands have already been demonstrated, although the extent and magnitude of these effects are not well known. A workshop is needed to develop a focused wetland monitoring program to address this specific question.

ii) A first pass regional, remote sensing assessment study could assess the potential effects of the mine development aerial deposition gradient on wetlands located within the main aerial deposition plume/ pathway compared to those in reference areas. This study would use the same imagery and some of the same field assessment sites and data as study 1Ai, but the study design would target wetlands within the aerial deposition pathway/ plume and appropriate reference areas.

Potential remote sensing indicators are:

- Wetland vegetation health and productivity, from hydrospectral imagery.

Field validation and ground truthing will be needed. Again, this field work can coordinate and use some of the same field assessment sites and data as study 1Ai. Potential field indicators are:

- Vegetation community quadrats, including productivity
- Wetland delineation and classification

- Existing chemistry data from previous deposition studies and models (e.g. passive air sampling data, snow survey sample data, lichen and moss N tissue concentrations).
- Any other critical chemistry data to fill existing data gaps.

iii) A first pass study of the extent and magnitude of the potential aerial deposition gradient associated with oil sands mines on wetland condition adjacent to oil sands mines could be determined through:

- A workshop to assess and evaluate the optimization of existing research studies, and monitoring networks to inform this question. Considerable research and monitoring has been conducted on aerial deposition extent and magnitude, as well as studies on ecological response in wetlands. A workshop is needed to bring these various researchers together to inform the design of this study, including:

  - WBEA air monitoring program
  - Snow survey monitoring and research
  - Passive air samplers
  - Environment Canada air researchers from JOSM studies
  - Bill Shotyk and Jonathan Martin's research teams

    Zhang Y**,** Shotyk W, Zaccone C, Noernberg T, Pelletier R, Bicalho B, Froese D, Davies LJ, Martin JW. 2016. Airborne petcoke dust is a major source of polycyclic aromatic hydrocarbons in the Athabasca oil sands region. *Environmental Science & Technology*.

  - Melanie Vile, Kelman Wieder and Dale Vitt (researched and monitored effects of aerial deposition on bog productivity, and effects of fire) – WBEA monitoring contract focused on ecosystem responses of bogs (considered wetland type most sensitive to aerial deposition from oil sands mines) to N and S deposition from 2008 to 2013. Sites chosen at varying distances from the oil sands mining area. Considerable work on identifying bioindicators and SOPs including lichen and moss species, nutrient content and ratios of plant species tissues, long term trends of increasing N concentrations of plant tissues, increasing N accumulation rates in peat sediment cores based on Pb210. A final report and monitoring recommendations can be found here:

    (http://www13.homepage.villanova.edu/kelman.wieder/WBEA_files/FINAL%20REPORT%2020%20October%202014.pdf)

If effects are detected by the core monitoring program (above) then the subsequent tiered monitoring questions are as follows:

2. Is the extent and magnitude of the change in time and space sufficiently understood to be able to evaluate the relevance of the change? If unknown, then extent and magnitude monitoring study may be needed.
3. Is the cause of the effects sufficiently well understood to evaluate ecological significance, and to be able to define corrective actions? If unknown, an Investigation of cause study may be needed.
4. What are the potential solutions/ mitigation/ corrective measures to the effects? If unknown, then an Investigation of solutions study may be needed.

Key Drivers

The key drivers of oil sands mine development considered most likely to cause effects on wetland condition are:

1) Hydrologic alteration including changes in flow, connectivity and depressurization of surface water and groundwater.

2) Aerial deposition from oil sands operations.

Other drivers need to be understood to interpret whether effects are due to oil sands mine development or other confounding factors. These natural drivers of wetlands should be incorporated into the design of a broader regional wetland monitoring program including:

3) Climate (variability and change) - Key natural driver. Understand natural variation in precipitation and evaporation across the oil sands region.

4) Fire - Key natural driver

5) Key landscape attributes

   Traditionally, conceptual landscape models of wetland distribution, extent and class have been based primarily on topographically defined watersheds and runoff. However, on the Boreal Plains the distribution of wetlands are linked to hierarchical factors controlling hydrologic behaviour and defined by variations in climate, bedrock permeability, surficial geology permeability, soil type and depth, and finally topography (Devito et al. 2005).

6) Invasive species – This may be an important driver at some sites or in the future, but for now considered a secondary driver.

7) Land disturbance

This driver will affect cumulative wetland change or alteration to extent and class, and will be affected by oil sands mine development, as well as many other sectors in the oil sands mine region (e.g. forestry, municipal development, other oil and gas activities). There are large direct losses of wetland area, which are best-tracked and monitored as part of a wider, regional wetland monitoring program, so the results can be compared across sectors. This driver-stressor-indicator is important for wetland management decisions and monitoring needs under the Alberta Wetland Policy and Regional Land Use Planning.

a) Stressors include:

    i) Percentage disturbed land

    ii) Landscape fragmentation

b) Beaver activity – secondary, localized stressor/ agent of change.

Key Stressors

Stressor - An action, agent, or condition that impairs the structure or function of a biological system.

Key stressors associated with oil sands mine development considered the most likely to cause a wetland response:

- Distance below ground to water table and water flow connectivity – these stressors are linked to the hydrologic alteration driver.
- Salts/ Cations-Anions/ EC in water are a stressor associated with the hydrological alteration driver. Relative influence of groundwater and surface water inflows can influence salt concentration. Also linked to changes in evaporation.
- Nitrogen concentration or contaminants (metals, Hg, other) – these stressors are linked to the aerial deposition driver.
- pH in water –
    - linked to aerial deposition driver and acidification pathway.
    - Also, water alteration (GW vs. SW relative inputs) could affect pH in water.
    - Acid lakes program
    - Wetlands acidic – lots of humic acids naturally.

Key Indicators

Recommend the monitoring program select indicators to best assess the key oil sands mine questions (identified above) and associated key drivers (hydrologic alteration and atmospheric deposition) – key stressors (e.g. changes to water table depth, increases in salt concentration, increases in N concentration) – and key response pathways.

Indicator selection criteria should include organisms that are abundant, exposed and be suitable for measuring the key driver –stressor –response pathway. Other important criteria are balanced, relatively easy to measure (cost-effective), not redundant, and will trigger a concern when relevant change is present.

- Key environmental indicators based on key drivers and stressors - (e.g. surface water quality (e.g. TSS, EC, Temp, Alkalinity, Salinity, cations and anions, pH), water quantity (water table depth, hydrologic connectivity, meteorological data), stable isotopes, N concentration in water).
- Key biological responses – Vegetation community quadrats recommended for core wetland monitoring program. Many measures are embedded in others (e.g. measure vegetation community diversity will also generate data on species composition, moss, lichens, rare plants, focal species). Other biological indicators (e.g. amphibians) may be monitored as part of an extent and magnitude monitoring program, to assess the extent and magnitude of the effect, i.e. are effects causing multiple biological responses?
- Other potential biological indicators where relationships to key stressor – performance indicators are known (e.g. N concentration in bioindicator lichens and mosses in bogs for atmospheric deposition driver).
- Other wetland species (e.g. amphibian health, yellow rails, waterfowl) are being studied through other monitoring programs for other management needs and objectives (e.g. species of concern, biodiversity).
- Aboriginal wetland values have not been incorporated, and could be integrated at a later stage of the monitoring program development.

Glossary

Driver - A driver is any natural or human induced factor that directly or indirectly causes a change in an ecosystem.

Effect – A change outside the range of natural variability of the reference conditions.

Stressor – An action, agent, or condition that impairs the structure or function of a biological system.

Pathway – The mechanism through which an environmental stressor(s) influences an environmental response(s).

Response - Any dependent variable affected by a stressor.

Performance Indicator – A measurable characteristic of the environment that has been correlated or causally linked to effects that an ecosystem has experienced.